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# NINTH QUARTERLY PROGRESS REPORT

1 JULY 1978 TO 30 SEPTEMBER 1978

CONTRACT DAAB07 - 76 - C - 0041

MANUFACTURING METHODS AND TECHNIQUES FOR MINIATURE HIGH VOLTAGE HYBRID MULTIPLIER MODULES

PLACED BY:

NIGHT VISION AND ELECTRO - OPTICAL LABORATORIES

U.S. ARMY ERADCOM, FORT BELVOIR, VA., 22060

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The results of further life-testing of rectangular and curved multipliers is discussed.

The commencement of the Confirmatory Sample phase is described including improvements in the manufacturing methods.

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# MANUFACTURING METHODS AND TECHNIQUES FOR MINIATURE HIGH VOLTAGE HYBRID MULTIPLIER MODULES.

(15)

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PREPARED BY: B. GRANT GORDON P.ENG.

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## ABSTRACT

The progress made during the ninth quarter of work on the Manufacturing and Technology Programme for Miniature High Voltage Multiplier Modules is described in this report.

The results of further life-testing of rectangular and curved multipliers is discussed.

The commencement of the Confirmatory Sample phase is described including improvements in the manufacturing methods.

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## LIST OF ILLUSTRATIONS

## PURPOSE

This Contract covers component designs, mounting and interconnection techniques, tooling and test methods and other manufacturing methods and techniques required for production of rectangular and curved miniature high voltage multiplier modules. These units are to be used in low cost power supplies for image intensifier tubes. The full scope and details of the specification are given in Appendix A to the Eighth Quarterly Report.

Major milestones in this program consist of delivery of the following items:

(1) First and second engineering samples and test data.
(2) Production line layout and schedule.
(3) Confirmatory samples and test data.
(4) Production line set-up.
(5) Pilot production run.
(6) Production rate demonstration.
(7) Preparation and publication of a final report.

The general approach is to design and set-up a cost-effective production capability, utilizing already established device technologies and materials, and to demonstrate the production line capability to fabricate at the rate of 125 acceptable units per 40 hour week.

## GLOSSARY OF SPECIAL TERMS

**Capacitor bank:** - Ceramic wafer with metallizations which perform the function of a number of capacitors connected in parallel (parallel bank) or in series (series capacitor bank).

**Cure:** - To change the physical properties of a material by chemical reaction or by the action of heat and catalyst.

**Flash test:** - Test consisting of instantaneous application of voltage at its specified value to the part.

**Hybrid:** - Technology combining thick-films (capacitor banks) with discrete devices (rectifiers).

**Multiplier Modules:** - Device consisting of capacitor banks and rectifiers connected and packaged to perform voltage multiplication and rectification.

**Pad:** - The metallized area on the ceramic bank acting as a plate of a capacitor and used to make an electrical connection to it.

**Rectifier:** - Semiconductor device with one or more p-n junctions connected in series.

**Rectifier-substrate Assembly:** - A substrate with rectifiers placed and secured within it.

Substrate: - Part of a multiplier module consisting of a piece of insulating material machined to accommodate the rectifiers and support the capacitor banks.

## LIST OF SYMBOLS AND ABBREVIATIONS

| | | |
|---|---|---|
| ic | - | charging current (μA) |
| $C_x$ | - | measured capacitance (pF) |
| D.F. | - | dissipation factor (%) |
| f | - | frequency (KHz) |
| $C_i$ | - | input capacitance (pF) |
| $I_L$ | - | load current (nA) |
| $v_r$ | - | ripple voltage (V) |
| $V_B$ | - | breakdown voltage (V) |
| $V_i$ | - | input voltage (Vp-p) |
| $V_o$ | - | output voltage (V d.c.) |
| $\eta$ | - | efficiency (%) |

## 1. INTRODUCTION

This report describes briefly the progress in the Manufacturing Methods and Techniques for Miniature High Voltage Hybrid Multiplier Modules Program, made during the latest calendar quarter.

In the First Quarterly Report the design and the manufacturing process for rectangular and curved multiplier modules were described. Prototype rectifier-substrate assemblies were fabricated and then redesigned to simplify the assembly operation. The specification covering the requirements for the multiplier modules forms Appendix A of the Report.

In the Second Quarterly Report results of the electrical evaluation of the first sample batch of rectangular capacitor banks TSK 25-250 and TSK 25-251 were given, the choice of the rectifier was made and electrical test results were presented on non-modular multipliers fabricated with TSK 25-250 and TSK 25-251 capacitor banks and standard HV20PD four-junction rectifiers, to evaluate these components.

In the Third Quarterly Report results of electrical tests on rectangular multiplier modules were presented.

For an input voltage of 1 KV, efficiencies above 96% under no-load conditions and above 95% with 500 nA load currents were achieved for all multipliers assembled with TSK 25-250 and TSK 25-251 and three-chip rectifiers. Low ripple voltages, input capacitances and charging currents were also measured on these multipliers. Results of the mechanical and electrical evaluation of TSK 25-249 curved capacitor banks were also presented in the Third Quarterly Report.

In the Fourth Quarterly Report work on impregnation and coating of the multipliers was discussed as well as some problems associated with the fabrication of the rectifier-substrate assemblies. The fabrication of rectangular and curved multipliers for the First Engineering Sample was discussed.

In the Fifth Quarterly Report were presented the results of electrical performance testing at the room, high ($+52^{o}C$) and low ($-54^{o}C$) temperatures, as well as effects of thermal shock, and high and low temperature storage.

In the Sixth and Seventh Quarterly Reports were presented the results of testing of rectangular and curved multipliers to the Second Engineering Sample requirements,

steps to improve the frequency performance of the multipliers and optimization of the rectifiers for these devices, as well as results of life testing of multipliers.

In the Eighth Quarterly Report the results of the reliability testing of rectangular and curved multipliers to the Second Engineering Sample requirements were analyzed and further steps to improve the performance of the multipliers and optimize the rectifiers for these devices were discussed.

## 2. FABRICATION AND EVALUATION OF MULTIPLIERS

### 2.1 General

The Programme Manager has received formal authorization to proceed to the Confirmatory Sample phase from the Administrative Contracting Officer, Major S.L. Thacher, U.S. Army CERCOM.

### 2.2 Reliability Testing of Voltage Multipliers

The four (4) encapsulated multiplier modules successfully completed the life test with 2592 hours on each unit. This brings the total times to:

5208 hours for unit #57

3862 hours for unit #76 and 8A

2592 hours for unit #82

for a combined figure of 15,524 unit hours. Therefore, overall, our life test produced results of:

8004 hours on 6 pcs (1000 Vp-p, unencapsulated)

8926 hours on 9 pcs (1150 Vp-p, unencapsulated)

10,416 hours on 5 pcs (1150 Vp-p, encapsulated)

for a total of 27,346 unit hours on 12 pieces.

Further life tests will be conducted on overrun multipliers from the confirmatory sample manufacture and all such units will be encapsulated to eliminate any corona problems.

## 2.3 Multiplier Design

The evaluation lot of 10,000 rectifier leads (HVRO4M-13) were received on 23 August. This enabled us to proceed with the manufacture of HSC3 devices (part number RD0058) using the thin nailhead leads. By the end of September we had received 480 rectifiers with another 1423 in various stages of manufacture.

Our model shop fabricated and delivered to us 100 pieces each of the rectangular and curved substrate plates made from the polyimide Vespel SP-1 material. The inspection data is presented in Tables 1 and 2 for the rectangular and curved substrates, respectively.

These materials enabled us to commence manufacture of 38 substrate assemblies; 20 rectangular and 18 curved. Since these substrates are polyimide, we

were able to cure the potting epoxy at a temperature of 240°C (compared to the 200°C previously used for the G-10 glass epoxy board).

As the loading of the devices into the substrates is difficult and time consuming - especially when using clips as we had in the past - we designed fixtures to improve the operation. These fixtures (illustrated in Figures 3 and 4) provide stability to the assembly and allow faster loading of the rectifiers as well as superior potting. This is a vast improvement over the previous method although one problem has manifested itself. The loading of the rectifiers into the substrates is simple provided one is careful, however, it is easy to jar a substrate out of its location and upset it. Therefore, some method of holding the substrate down onto the fixture during loading and encapsulation is required. We are presently examining this problem and will modify the fixtures accordingly.

## 3. CONCLUSIONS

The life testing indicates that the multipliers, as fabricated, will meet the reliability requirements if encapsulated for the test.

The fixtures built for substrate loading substantially improve the assembly technique.

Further changes will be incorporated to ease the manufacture of the multiplier modules and to improve their reliability. The capacitor and rectifier designs are finished and the substrates will need only minor modifications at most.

## 4. PROGRAMME FOR NEXT QUARTER

4.1 Continue manufacture of the confirmatory sample lot.

4.2 Commence testing of the confirmatory sample lot.

## 5. PUBLICATIONS AND REPORTS

No reports or publications were made on the work associated with this program during the current quarter.

## 6. IDENTIFICATION OF PERSONNEL

Brief descriptions of the background of technical personnel involved were included in the preceding Quarterly Progress Reports.

On 1 September, Dr. M. Korwin-Pawlowski left the employ of Erie Technological Products of Canada and was replaced by Mr. B. Grant Gordon, P.Eng., as Programme Manager on this contract. During the Ninth quarter of the program the following persons worked in their area of responsibility:

| INDIVIDUAL | RESPONSIBILITY | HRS. SPENT |
|---|---|---|
| Dr. M. Korwin-Pawlowski | Programme Manager (to August 8, 1978) | 77 |
| B.G. Gordon | Programme Manager (from August 8, 1978) | 91 |
| D. Platt | Manager, Quality Assurance and Control, High Voltage Products | 6 |
| D. Archard | Senior Test Technician | 10 |
| M. Black | Production Supervisor, Rectifiers | 2 |
| K. Cram | Draughtsman | 16 |
| C. Grills | Senior Engineering Technician | 95 |
| L. Macklin | Draughtsman | 5 |
| D. Regan | Senior Engineering Technician | 16 |
| | Manufacturing Personnel | 22.4 |
| TOTAL HOURS | - in quarter | 340.4 |
| TOTAL HOURS | - to date | 4379.4 |

TABLE 1

Mechanical Inspection Data for TSK-312-104'A' Substrate Plates (Polyimide Material)

| Hole # | A | B | C | D | E | F | G | H | J | K | L | M | N |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Unit A | | | | | | | | | | | .2510 | .0700 | .5180 |
| 1 | .0348 | .0508 | .0192 | .0208 | .0869 | .0043 | .0757 | .0319 | .0918 | .0397 | | | |
| 2 | .0390 | .0490 | .0205 | .0262 | .0891 | | | | | | | | |
| 3 | .0367 | .0514 | .0193 | .0250 | .0887 | | | | | | | | |
| 4 | .0400 | .0501 | .0193 | .0221 | .0869 | | | | | | | | |
| 5 | .0394 | .0499 | .0193 | .0298 | .0860 | | | | | | | | |
| 6 | | .0504 | .0183 | .0322 | .0906 | .0100 | .0775 | .0337 | .0867 | .0387 | | | |
| 7 | .0256 | .0556 | .0184 | .0300 | | .0050 | | | | | | | |
| 8 | .0386 | .0528 | .0203 | .0281 | | | | | | | | | |
| 9 | .0374 | .0509 | .0204 | .0320 | | | | | | | | | |
| 10 | .0422 | .0513 | .0199 | .0329 | | | | | | | | | |
| 11 | .0349 | .0503 | .0183 | .0274 | | | | | | | | | |
| 12 | | .0486 | .0178 | .0260 | | .0074 | | | | | | | |
| Unit B | | | | | | | | | | | .2510 | .0710 | .5170 |
| 1 | .0363 | .0509 | .0216 | .0233 | .0885 | .0067 | .0730 | .0296 | .0848 | .0377 | | | |
| 2 | .0377 | .0508 | .0209 | .0249 | .0866 | | | | | | | | |
| 3 | .0340 | .0513 | .0200 | .0239 | .0876 | | | | | | | | |
| 4 | .0397 | .0574 | .0211 | .0247 | .0877 | | | | | | | | |
| 5 | .0313 | .0505 | .0208 | .0253 | .0859 | | | | | | | | |
| 6 | | .0528 | .0218 | .0255 | .0835 | .0112 | .0630 | .0291 | .0877 | .0371 | | | |
| 7 | .0393 | .0522 | .0221 | .0198 | | .0046 | | | | | | | |
| 8 | .0386 | .0514 | .0217 | .0222 | | | | | | | | | |
| 9 | .0374 | .0542 | .0227 | .0232 | | | | | | | | | |
| 10 | .0391 | .0506 | .0227 | .0264 | | | | | | | | | |
| 11 | .0366 | .0513 | .0226 | .0268 | | | | | | | | | |
| 12 | | .0502 | .0209 | .0263 | | .0105 | | | | | | | |

Notes: (i) All measurements are in inches.

(ii) See Figure 1 for dimensioning.

TSK-312-104'A'

Dimensioning of Rectangular Substrate Plate

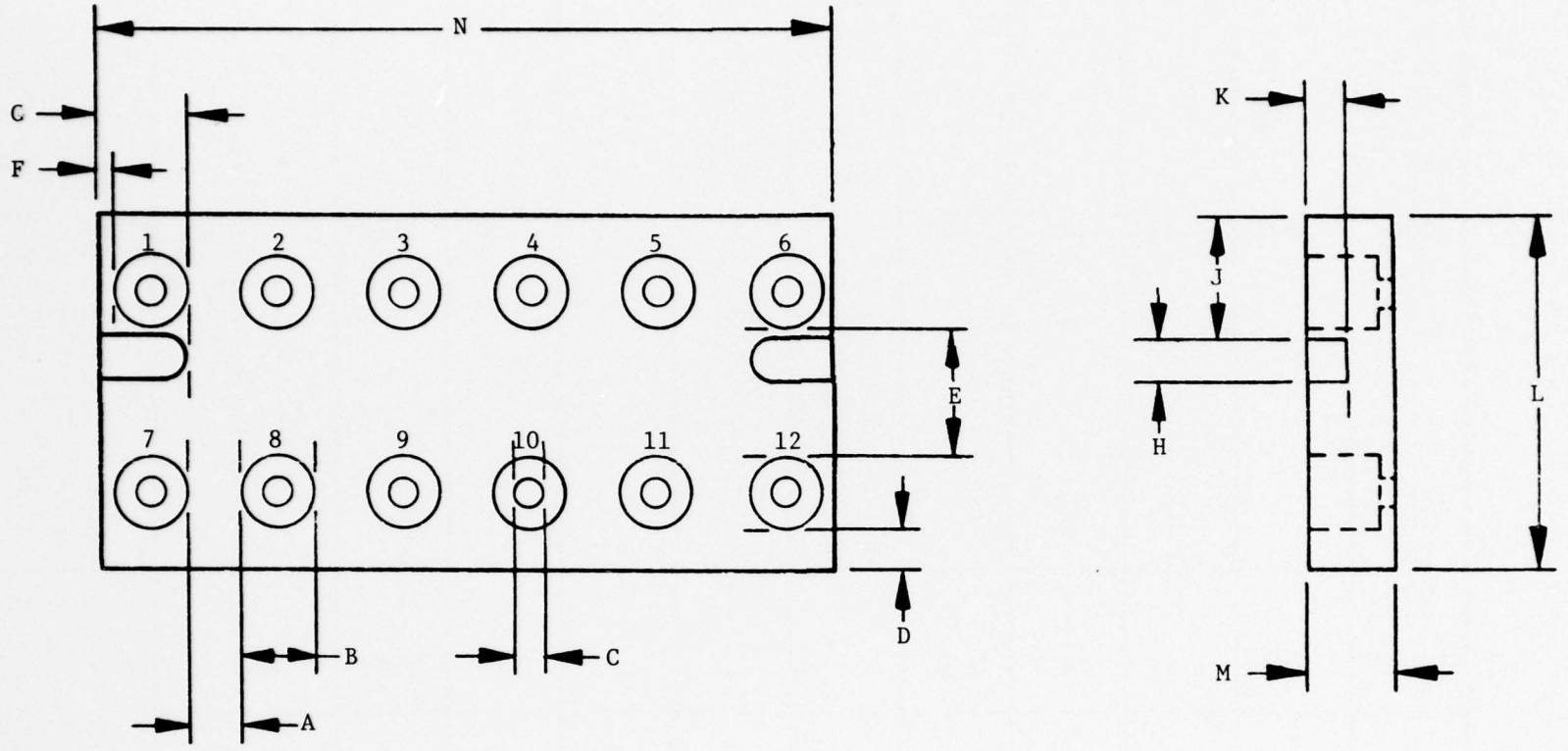



FIGURE 1

TABLE 2a

Mechanical Inspection Data for TSK-313-104'A' Substrate Plates (Polyimide Material)

| Hole # | A | B | C | D | E | F | G | H | J | K |
|---|---|---|---|---|---|---|---|---|---|---|
| Unit A | .0325 | .1051 | .1473 | | | .0878 | .1017 | .0340 | .0690 | .0337 |
| 1 | | | | .0516 | .0209 | | | | | |
| 2 | | | | .0520 | .0211 | | | | | |
| 3 | | | | .0520 | .0202 | | | | | |
| 4 | | | | .0524 | .0194 | | | | | |
| 5 | | | | .0488 | .0201 | | | | | |
| 6 | | | | .0523 | .0218 | | | | | |
| 7 | | | | .0548 | .0202 | | | | | |
| 8 | | | | .0509 | .0205 | | | | | |
| 9 | | | | .0474 | .0215 | | | | | |
| 10 | | | | .0517 | .0214 | | | | | |
| 11 | | | | .0519 | .0206 | | | | | |
| 12 | | | | .0453 | .0207 | | | | | |
| Unit B | .0346 | .1053 | .1515 | | | .0850 | .0988 | .0339 | .0680 | .0303 |
| 1 | | | | .0514 | .0208 | | | | | |
| 2 | | | | .0520 | .0209 | | | | | |
| 3 | | | | .0520 | .0206 | | | | | |
| 4 | | | | .0515 | .0209 | | | | | |
| 5 | | | | .0515 | .0203 | | | | | |
| 6 | | | | .0518 | .0214 | | | | | |
| 7 | | | | .0527 | .0204 | | | | | |
| 8 | | | | .0521 | .0212 | | | | | |
| 9 | | | | .0520 | .0203 | | | | | |
| 10 | | | | .0510 | .0200 | | | | | |
| 11 | | | | .0506 | .0209 | | | | | |
| 12 | | | | .0531 | .0215 | | | | | |

Notes: (i) All measurements are in inches.

(ii) See Figure 2a for dimensioning.

TSK-313-104'A'

Dimensioning of Curved Substrate Plate

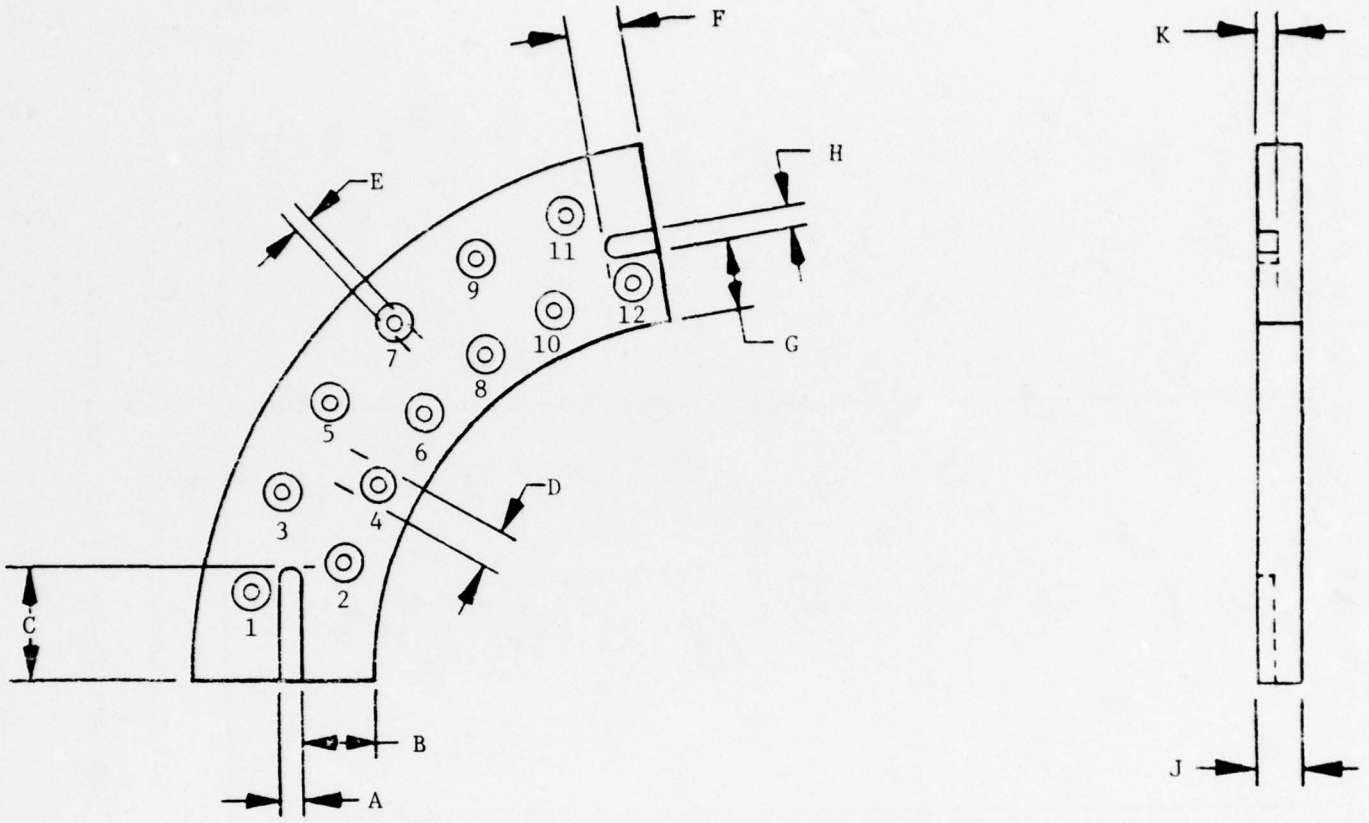



FIGURE 2a

TABLE 2b

Additional Mechanical Data for TSK-313-104'A' Substrates

| | Unit A | Unit B |
|---|---|---|
| R1 | .506 | .505 |
| R2 | .755 | .753 |
| R3 | .568 | .565 |
| R4 | .684 | .670 |
| A1 | $10^{o}$ | $10^{o}$ |
| A2 | $15^{o}40'$ | $16^{o}$ |
| A3 | $21^{o}40'$ | $22^{o}$ |
| A4 | $27^{o}25'$ | $27^{o}45'$ |
| A5 | $33^{o}25'$ | $33^{o}40'$ |
| A6 | $39^{o}15'$ | $39^{o}45'$ |
| A7 | $45^{o}25'$ | $46^{o}$ |
| A8 | $51^{o}20'$ | $51^{o}45'$ |
| A9 | $57^{o}25'$ | $57^{o}50'$ |
| A10 | $63^{o}05'$ | $63^{o}30'$ |
| A11 | $69^{o}05'$ | $69^{o}40'$ |
| A12 | $75^{o}$ | $75^{o}35'$ |
| A13 | $79^{o}$ | $79^{o}50'$ |

Notes: (i) All measurements are in inches unless specified.

(ii) See Figure 2b for dimensioning.

TSK-313-104'A'

Dimensioning of curved substrate plate

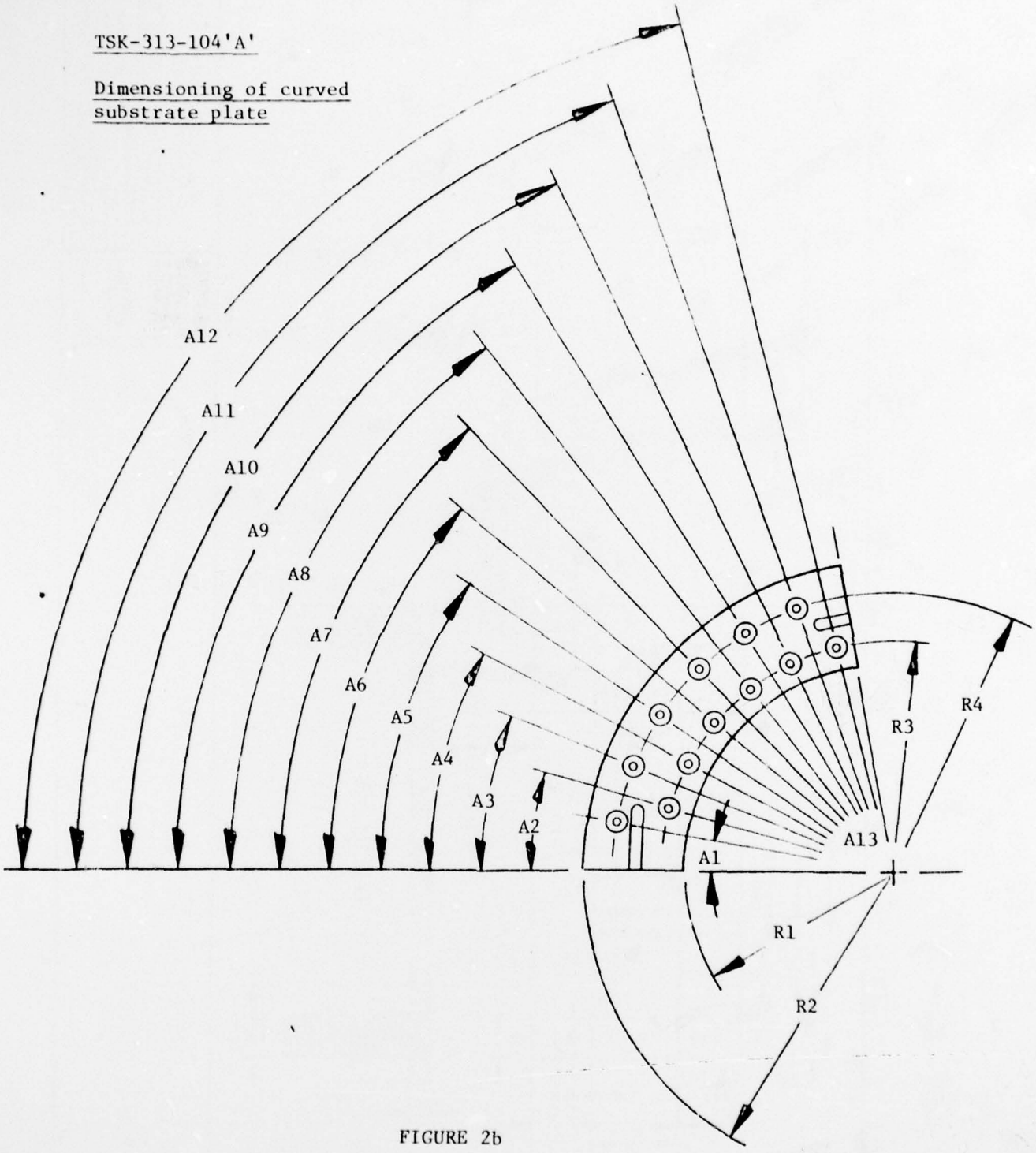
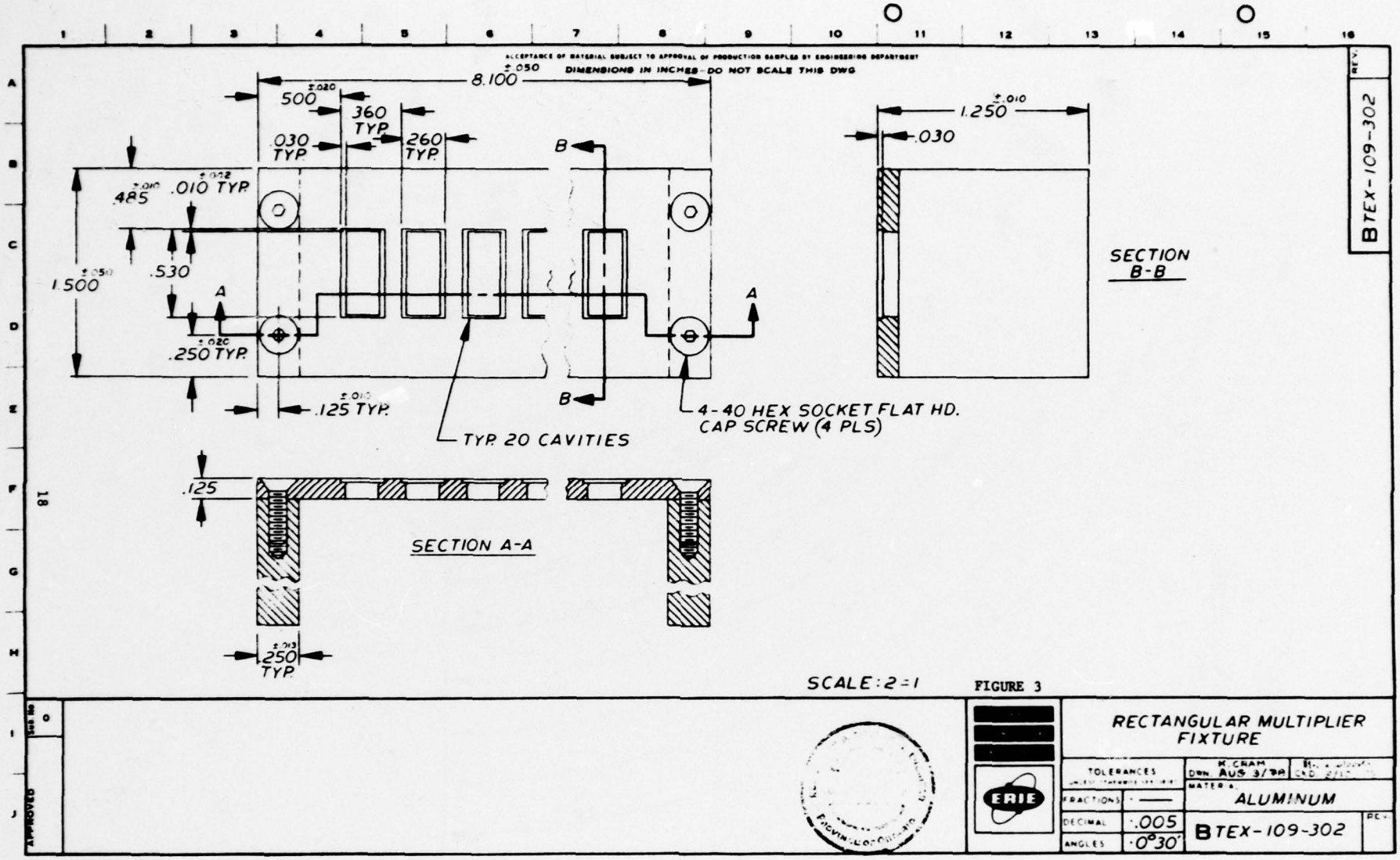
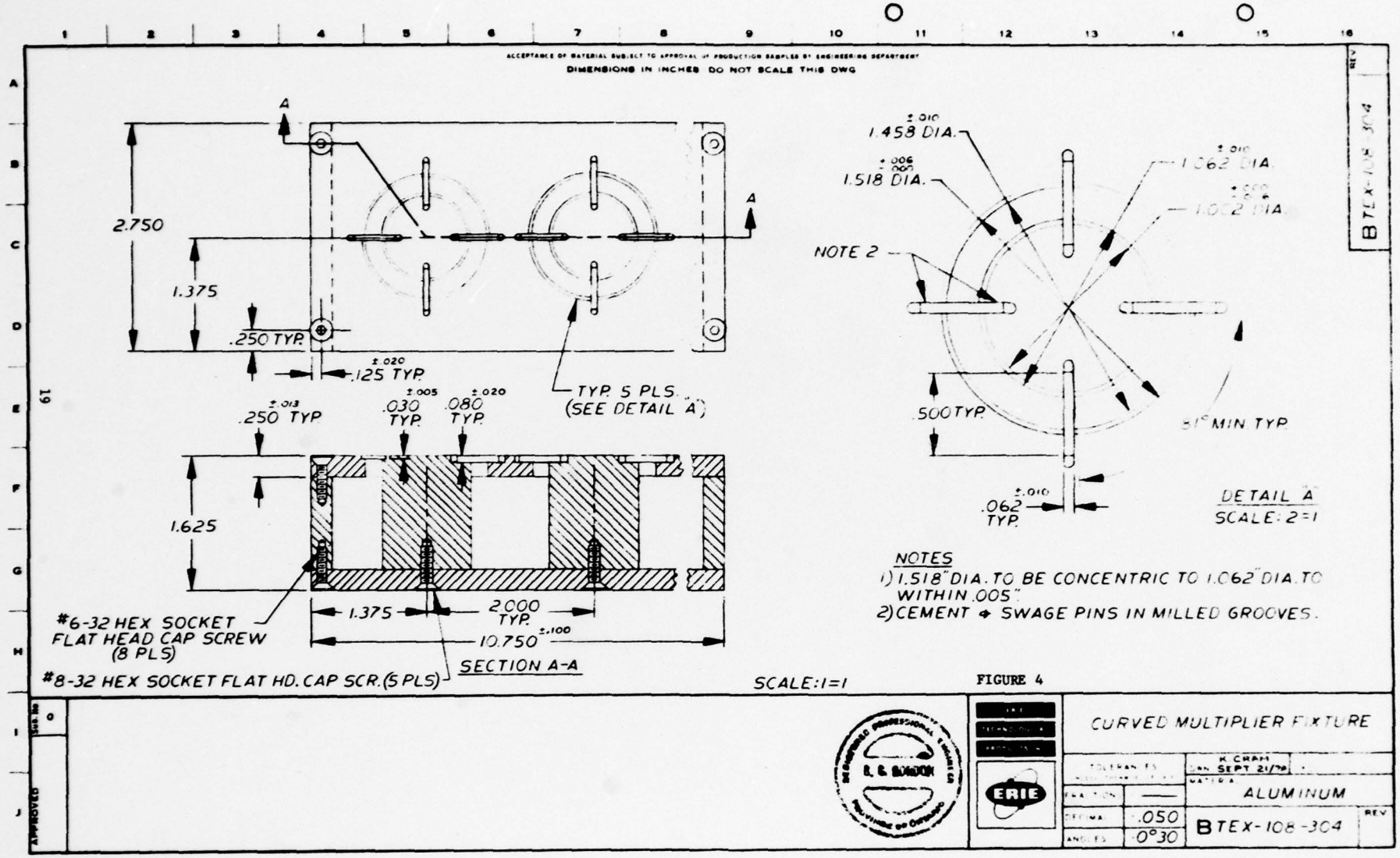



FIGURE 2b


ACCEPTANCE OF MATERIAL SUBJECT TO APPROVAL OF PRODUCTION SAMPLES BY ENGINEERING DEPARTMENT
DIMENSIONS IN INCHES - DO NOT SCALE THIS DWG
8.100
.500
.360 TYP.
.030 TYP.
.260 TYP.
.485
.010 TYP.
.530
1.500
.250 TYP.
.125 TYP.
TYP. 20 CAVITIES
4-40 HEX SOCKET FLAT HD. CAP SCREW (4 PLS)
1.250
.030
SECTION B-B
.125
SECTION A-A
.250 TYP.
SCALE: 2=1
FIGURE 3
RECTANGULAR MULTIPLIER FIXTURE
ALUMINUM
BTEX-109-302
TOLERANCES
FRACTIONS
DECIMAL .005
ANGLES ±0°30'
APPROVED


ACCEPTANCE OF MATERIAL SUBJECT TO APPROVAL OF PRODUCTION SAMPLES BY ENGINEERING DEPARTMENT
DIMENSIONS IN INCHES DO NOT SCALE THIS DWG
2.750
1.375
.250 TYP.
.125 TYP.
TYP. 5 PLS. (SEE DETAIL 'A')
.250 TYP.
.030 TYP.
.080 TYP.
1.625
#6-32 HEX SOCKET FLAT HEAD CAP SCREW (8 PLS)
#8-32 HEX SOCKET FLAT HD. CAP SCR. (5 PLS)
1.375
2.000 TYP.
10.750
SECTION A-A
SCALE: 1=1
1.458 DIA.
1.518 DIA.
1.062 DIA
1.062 DIA
NOTE 2
.500 TYP.
31° MIN TYP.
.062 TYP.
DETAIL A
SCALE: 2=1
NOTES
1) 1.518" DIA. TO BE CONCENTRIC TO 1.062" DIA. TO WITHIN .005"
2) CEMENT ◆ SWAGE PINS IN MILLED GROOVES.
BTEX-108-304
FIGURE 4
CURVED MULTIPLIER FIXTURE
K CRAPP
SEPT 21/79
ALUMINUM
.050
0°30
BTEX-108-304
ERIE
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